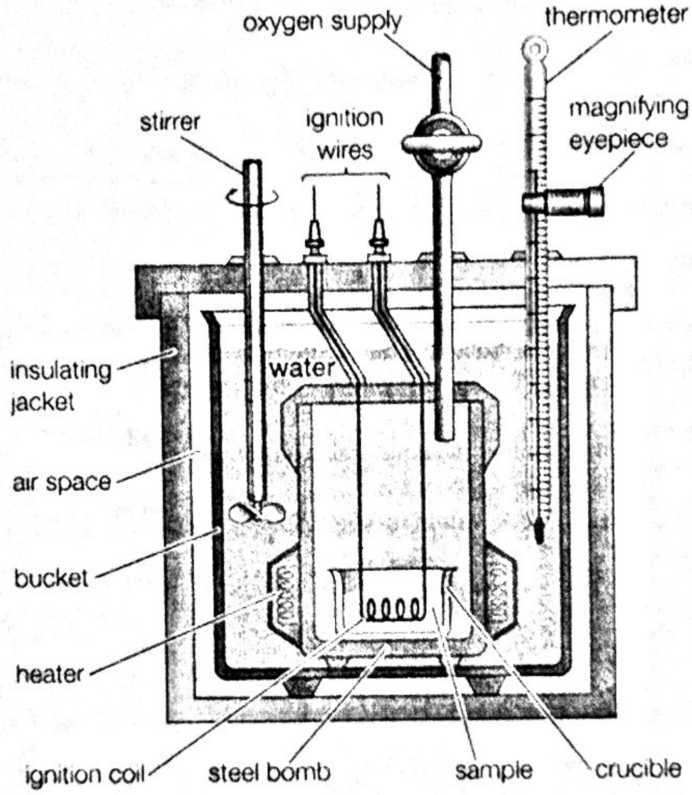
CT05D06 – Calorimetry Problems (They are the Bomb)

Name ......KEY......

Directions: Solve each of the following calorimetry problems. Show ALL work for credit. **Box** in or **circle** all answers. **SHOW UNITS** at **ALL** times.

Some of the problems involve using what is referred to as a bomb calorimeter. A bomb calorimeter is an extremely well insulated calorimeter (similar what you made in the food energy production lab) but NO energy leaks to the outside. All energy is absorbed by the bomb and/or the water in the bomb. The heat capacity of the bomb must be taken into account along with the water.



c = specific heat

$\underline{C} = mc$

$\therefore q = mc\Delta T$

$q = \underline{C}\Delta T$

$q_{syst} = q_{H_2O} + q_{bomb} + q_{material}$

$q_{syst} = 0$ (no change)

$\therefore q_{material} = -(q_{H_2O} + q_{bomb})$

$q_{mat} = -((mc\Delta T)_{H_2O} + (\underline{C}\Delta T)_{bomb})$

$q_{bomb} = \underline{C}\Delta T$

$\underline{C}_{bomb} = \_\_\_ \text{ J/°C}$

$q_{H_2O} = mc\Delta T$

$c_{H_2O} = 4.184 \text{ J/g°C}$

1. A 1.55 g of CH_4O sample is burned in a calorimeter. If the molar heat of combustion of CH_4O is -725 kJ/mol, and assuming that the 2.0 L of water absorbed ALL of the heat of combustion, what temperature change did the water undergo?

First, find how many kJ/mol

$1.55\text{g } CH_4O \times \frac{1 \text{ mol } CH_4O}{32.05\text{g } CH_4O} \times \frac{-725 \text{ kJ}}{1 \text{ mol } CH_4O} = -35.06 \text{ kJ or } -35{,}060 \text{ J} = q_{CH_4O}$

$+35{,}060 \text{ J} = q_{H_2O}$

Then, find g H_2O

$2.0\text{L } H_2O \times \frac{1000\text{g } H_2O}{1\text{L } H_2O} = 2000\text{g}$

Then, find ΔT

$q_{H_2O} = mc\Delta T$

$+35{,}060 \text{ J} = (2000\text{g})(4.184 \text{ J/g°C})\Delta T_{H_2O}$

$\boxed{\Delta T_{H_2O} = 4.19 °C}$

2. Sucrose, $C_{12}H_{22}O_{11}$, reacts with oxygen according to the reaction.

$$C_{12}H_{22}O_{11}\,(s) + 12\,O_2\,(g) \rightarrow 12\,CO_2\,(g) + 11\,H_2O\,(l)$$

Calculate the heat produced per mole of sucrose when 2.75 g of $C_{12}H_{22}O_{11}$ are reacted with excess oxygen in a bomb calorimeter containing 4.80 kg of water. The temperature change measured is 2.10 degrees C. The heat capacity of the calorimeter is 2540 J/degrees C.

*Using bomb calorimeter, so $q_{rxn} = -(q_{bomb} + q_{H_2O})$

$q_{sucrose} = -(q_{bomb} + q_{H_2O})$

$= -(C\Delta T_{bomb} + mc\Delta T_{H_2O})$

$= -(2540\ J/°C)(2.10°C) + (4800\ g)(4.184\ J/g°C)(2.10\ °C)$

$q_{sucrose} = \frac{-47{,}508\ J}{2.75\ g\ C_{12}H_{22}O_{11}} \times \frac{342.34\ g\ C_{12}H_{22}O_{11}}{1\ mol\ C_{12}H_{22}O_{11}} = 5{,}915{,}000\ J/mol$

or

5,915 kJ/mol

* Remember, this value is J/2.75 g → J/mol.

3. A 1.000 g sample of liquid hydrazine was burned in a bomb calorimeter containing 1.2 kg of water. The temperature increased from 24.620 to 27.900 degrees C. The bomb calorimeter by itself had a heat capacity of 836 J/K.

a) Calculate the energy absorbed by the bomb calorimeter by itself.
b) Calculate the energy absorbed by the water
c) Calculate the molar heat of combustion for the following reaction using the above information

$$N_2H_4\,(l) + O_2\,(g) \rightarrow 2\,H_2O\,(l) + N_2\,(g)$$

(a) $q_{bomb} = C\Delta T$

$= (836\ J/°C)(3.3°C)$

$q_{bomb} = 2758.8\ J$

(b) $q_{H_2O} = (1200\ g)(4.184\ J/g°C)(3.3°C)$

$q_{H_2O} = 16568\ J$

(c) $q_{rxn} = -(q_{bomb} + q_{H_2O})$

$= -(16568\ J + 2758.8\ J)$

$q_{rxn} = \frac{-19.327\ kJ}{1.000\ g\ N_2H_4} \times \frac{32.05\ g\ N_2H_4}{1\ mol\ N_2H_4}$

$q_{rxn} = -619.62\ kJ/mol$

4. A bomb calorimeter was calibrated by burning a sample of benzoic acid (C_6H_5COOH) which has a known heat of reaction of -3227 kJ/mol. When 1.890 g of benzoic acid is burned in the calorimeter, the temperature increased by -.6320 degrees C. Calculate the heat capacity of the calorimeter and its contents.

$q_{rxn} = \frac{-3227\ kJ}{1\ mol\ C_6H_5COOH} \times \frac{1\ mol\ C_6H_5COOH}{122.13\ g\ C_6H_5OH} \times 1.890\ g\ C_6H_5OH = -49.94\ kJ$

$q_{rxn} = C\Delta T$

$-49{,}940\ J = C\,(-0.6320°C)$

$C = 79{,}018\ J/°C$

5. Gram for gram, fats in food have much more chemical energy than sugar. One component of fat is stearic acid, $C_{18}H_{36}O_2$. When a sample of 1.02 g of stearic acid was burned completely in a bomb calorimeter, the temperature of the calorimeter rose by 4.26 degrees C. The heat capacity of the bomb is 0.45 kJ/degree C. Calculate the molar heat of combustion of stearic acid in kJ/mole.

$q_{bomb} = C\Delta T$

$q_{bomb} = (440\ J/°C)(4.26°C)$

$q_{bomb} = \frac{1,920\ J}{1.02\ g\ C_{18}H_{36}O_2} \times \frac{284.5\ g\ C_{18}H_{36}O_2}{1\ mol\ C_{18}H_{36}O_2} = 534,700\ J/mol$

or

$534.7\ kJ/mol$

6. When a reaction was carried out in a bomb calorimeter, 17.61 kJ of energy was released. The initial temperature was 22.418 degrees C. The heat capacity of the system was 17.68 kJ/ degree C. Calculate the final temperature of the calorimeter.

$q_{bomb} = C\Delta T$

$17.61\ kJ = (17.68\ kJ/°C)(T_f - 22.418\ °C)$

$T_f = 23.41°C$

7. Phileas Fogg, the character who went around the world in 80 days, was very fussy about his bathwater temperature. It had to be exactly 38.0 degrees C. You are his butler, and one morning while checking his bath temperature, you notice that its 42.0 degrees C. You plan to cool the 100.0 kg of water to the desired temperature by adding an aluminum duckie originally at freezer temperature (-24 degrees C). Of what mass must the aluminum duckie be? [C_{Al} = 0.900 J g^{-1} °C^{-1}; d_{H2O} = 1.00 g cm^{-3}]

$mc\Delta T = -mc\Delta T$

m_{H_2O} = 100kg

$T_{i\,H_2O}$ = 42.0°C T_f = 38.0°C

c_{H_2O} = 4.184 J/g°C

$T_{i\,Al}$ = -24°C

T_f = 38°C

m_{Al} =

c_{Al} = 0.900 J/g°C

$(100{,}000\,g)(4.184\ J/g°C)(-4°C) = -(m_{Al})(0.900\ J/g°C)(62°C)$

m_{Al} = 29,992 g or 29.992 kg

8. A certain material temperature increases by 1.0 degrees C for every 1560 J that it gains. A 0.1964 g sample of quinone (molar mass = 108.1 g) was burned and the surrounding materials temperature increased from 20.3 to 23.5 degrees C. Find the molar heat of combustion for quinone.

$q = C\Delta T$

C = 1560 J/°C

$q = (1560\ J/°C)(3.2°C)$

$q = \frac{4992\ J}{0.1964\,g\ Q} \times \frac{108.1\,g\ Q}{1\,mol\ Q}$ = 2,747,000 J/mol or 2,747 kJ/mol